LA-UR-19-20023
Approved for public release; distribution is unlimited.

Title: Broad Scope Analysis of the MOX Fuel Fabrication Facility and Disposition of Plutonium

Author(s): Bishop, Jessica Lyn
Psaila-Dombrowski, Maureen Justine
Kornreich, Drew Edward

Intended for: Report

Issued: 2019-01-07

Broad Scope Analysis of the MOX Fuel Fabrication Facility and Disposition of Plutonium

Jessica L. Bishop[1,2], Maureen J. Psaila-Dombrowski[2], Drew E. Kornreich[2]
[1]*University of Tennessee, Knoxville 37966*
[2]*Los Alamos National Laboratory*

Abstract:[1] The Plutonium Management and Disposition Agreement (PMDA), signed into effect in 2000, between the United States and Russia, was made in a post-Cold War effort to dispose of military-useable material, a combined 68 metric tons of weapon-grade plutonium. The United States has been pursuing a disposition path through conversion to MOX fuel for use in current commercial nuclear reactors. The Savannah River Site's (SRS) MOX Fuel Fabrication Facility (MFFF, the MOX facility) began construction in 2007 with intent to uphold the United States' half of the agreement. In the FY2017 budget, the Obama administration proposed a termination of the MFFF after lack of sufficient funding to the project, which caused paralyzing delays and drastically inflated costs for completion. Prolonged construction, piled costs, and divergent policies between shifting administrations have resulted in turmoil between the United States and Russia, culminating with the proposed abandonment of the MOX disposition path and being used as a justification by Russia to withdraw from the agreement until the United States is able to identify a clear plan, fulfilling the requirements set forth by the PMDA. The leading expedient to replace MOX fuel is the dilute and dispose method, which leaves uncertainty for the SRS MFFF and places reliance on New Mexico's Waste Isolation Pilot Plant (WIPP) to legally accommodate the additional and unaccounted waste. If the current capacity of WIPP proves insufficient, construction of a new repository for transuranic waste would only incur additional costs and regulatory burdens, along with extreme schedule delays. Future proposed adaptations of the SRS MFFF include pit production, which would require complex and costly alterations to be operational at the current site. Restrictions from Congress, such as mandating the proposed solution to abandoning MFFF must equal half of the costs required for completing the facility, have fueled severely underestimated quotations of these alternatives. The increasing pressure from both Russia and South Carolina government officials to make a decision could result in the pursuit of another doomed project, leaving the United States with even further sunk costs and strained international relations. This paper will summarize the involved history of the MFFF, explicate the recourses to salvage the facility for pit production, and provide postulation on the dilute and dispose method.

[1] This analysis was performed to support the requirements for the NEUP Fellowship awarded to Jessica L. Bishop.

I. Introduction

Deciphering intention in an era of political ambiguity is increasingly difficult, especially when speculating on nuclear issues. Initiatives to modernize the United States' nuclear arsenal are apparent in the current administration's Nuclear Posture Review (NPR), but tracing those motivations and their translation into all nuclear sectors is not so straightforward. The agreement between the United States and Russia to convert disposition plutonium, that is plutonium declared to be in excess of their defense-related needs, has been unsuccessful. The billions of dollars devoted to the construction of the MOX facility, with no useable facility, is a problem the Department of Energy (DOE). Alleged mishandling of funding, poor preparation in cost estimations, and redirected energy policy has put the State of South Carolina and the DOE at odds. Now the two must agree on how to proceed with the MOX facility – whether it be rerouted to pit production or continued construction of the Mixed-oxide Fuel Fabrication Facility (MFFF, MOX facility) and what that means for the disposition plutonium currently on site at Savannah River. Going forward, it is recommended not to dwell on the past mistakes, but learn from them and demonstrate only best practices in future projects. The purposes of this paper are to 1) highlight the history of this agreement and the MOX facility, and 2) offer support to the government's push for pit production at SRS from a national security perspective.

II. Historical Summary

The United States and Russia signed the Plutonium Management and Disposition Agreement in 2000, calling for the disposition of 34 metric tons of plutonium in an irretrievable manner agreed upon by both parties [1]. Within the agreement are a list of acceptable methods to eliminate the disposition plutonium, of which both parties decided on Mixed Oxide (MOX) fuel. MOX fuel, designed to incorporate extracted and oxidized weapon-grade plutonium into fuel pellets with uranium oxide, can be configured to fuel both light water reactors (LWRs) and fast reactors. The agreement received little to no attention for the first decade as both countries set to designing and constructing their respective fuel fabrication facilities, the United States beginning in 2007 and Russia in 2011 [2]. During this time, the Bush Administration developed the Global Nuclear Energy Partnership (GNEP), which encouraged the growth of advanced nuclear technology, specifically aimed toward the nuclear fuel cycle. The overarching goal of the partnership was to close the fuel cycle in the United States, sponsoring the Advanced Fuel Cycle Initiative (AFCI) and supporting development of reprocessing and enrichment capabilities. While not directly related, use of MOX fuel is readily incorporated into the underlying principles of the AFCI and GNEP. Despite these efforts, with the low estimate of $1 billion dollars for design and construction in 2002 blossoming to $4.8 billion in 2007, progress on the United States' MFFF began to slow [3].

In 2010, the Obama Administration changed the GNEP to the International Framework for Nuclear Energy Cooperation (IFNEC) – a correction for the inferred hypocrisy in the mission statement of the GNEP and the Nuclear Nonproliferation Treaty (NPT) [4]. This change eliminated the pursuit of United States domestic reprocessing and enrichment, undercut the goal of the AFCI, and can reasonably be designated as one of the root causes of the failure to implement the use of MOX fuel in the United States. The MFFF design and construction costs

proceeded to grow, reaching $7.78 billion in 2014 and totaling an estimated life cycle cost of $30 billion by 2015 [3]. Currently, the project is costing the taxpayer $1.2 million per day, with only modest progress being realized [5].

In the midst of these administrative changes and inflated costs, the Russian government began to question whether the United States would be able to meet their commitment to the PMDA. In 2015, when costs were decidedly too high, the United States proposed the idea of diluting and disposing of the plutonium. This would entail the plutonium be mixed with an inert material and buried at the country's only existing transuranic geological repository, the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. Russian officials expressed discontent for this method, stating that the plutonium would not be transformed to the degree required by the agreement. They also provided that the dilute and dispose method seemed foolish as so much time and effort initially went into the production of the Cold War Era plutonium, and to not utilize it in a way so as to extract some benefit (i.e., nuclear energy) would be imprudent [6]. Rising tensions over the United States' disregard for Russian cautions, the Russian invasion of Crimea in 2014, and subsequent United States-issued sanctions against the country, lead to Russia withdrawing from the PMDA in 2016 [7].

The above series of events has resulted in two major questions:

i. What happens to the MFFF site?
ii. What happens to the disposition plutonium?

The following sections will discuss the options moving forward and the implications these decisions will have on the greater nuclear energy future.

III. Methodology

Uncertainty in nuclear power as an energy source is rampant throughout the country, and policy makers are still scrambling to deal with nuclear waste generated since the technology's inception. Due to the overlapping nature of nuclear technology, analyzing any one matter requires a basic understanding of all nuclear issues to bring the full picture into focus. Not only does the analysis in this paper include a comprehensive literature review of policy surrounding the MFFF and the PMDA, including U.S.-Russian relations and fuel cycle policy, but is supported by additional research in the areas such as uranium mining, power production, and national security. The benefit of including this perspective in the report is to shape a more realistic view of the MFFF and PMDA. The MOX facility is evidently not just a construction project failed by lack of funding and the PMDA is not a standalone agreement for disarmament. However, the radius of influence affecting the decisions made on these two issues is more expansive than presumed.

IV. Moving Forward

Before beginning to address the future of the MFFF site, a more thorough understanding of the complications during the construction of the MFFF is necessary. Construction of the facility began in 2007 at the Savannah River Site (SRS) in South Carolina. Chicago Bridge & Iron Company

(CB&I) AREVA MOX Services was contracted because of their demonstrated experience in MOX fuel technology in their country of origin, France [8]. However, a myriad of oversights added delays and costly corrections, including things as trivial as accounting for the conversion of metric units to standard units. The adaptation of French regulations to meet United States' standards and lack of sufficient governmental budgeting only contributed to the facility's stalled growth. After the Obama Administration decided to abandon the MOX project, the facility received barely enough annual funding to keep the project alive. The allotment of approximately $300 million per year did not allow for any substantial progress, but because the prospect of dilute and dispose hadn't been thoroughly analyzed, the DOE would have had difficulty terminating the MOX facility construction without better definition of a viable alternative [3]. While the proposed dilute-and-dispose option appeared very attractive to the DOE, state officials in South Carolina did not accept this option. South Carolina senator Lindsey Graham has stated that the approach is not going to work [9]. He has expressed his disappointment toward the DOE for their inability to uphold their promises. This is a rather consistent theme seen in state-federal relationships when dealing with nuclear agreements and installations where the state often feels taken advantage of. In June 2018, the state of South Carolina took the DOE and NNSA to district court for their efforts to shut the MOX facility down. The judge, Julianna Michelle Childs, issued a federal injunction on the stop-work order proposed by the DOE and suspended the action until the court ruled in favor of the facility's closure.

A brief attempt was made by the Committee on Armed Services to separate the National Nuclear Security Administration (NNSA) from under the Department of Energy. The provision would have essentially created an autonomous body of the NNSA, one that is could have taken over as landlord for the Savannah River Site, which is currently operated by the Office of Environmental Management (EM) [10, 11]. While the Senate-approved bill was never signed into action, it came closer than anticipated and demonstrates the collective impatience toward the MOX facility progress and the efficiency of the Department of Energy to carry out its duties.

Turning the focus away from the perceived unfair treatment South Carolina may have received in regard to this facility, an analysis of fuel cycle economics can provide a more objective outlook on MOX fuel. In theory, MOX fuel is a very attractive and somewhat serendipitous concept – turning weapons-useable material into energy producing fuel.[2] The phrase "swords to plowshares" is often employed when discussing the technology. Additionally, the transformation of proliferation-prone plutonium into spent fuel is a relatively sufficient safeguard against nuclear terrorism. However, the tipping point for the decision on MOX fuel can be condensed to the fact that *it's just not economically sensible.* Enriched uranium is capable of fueling the nation's current light water reactors (LWRs) in an inexpensive way while delivering the same energy output. The infrastructure of nuclear reactor fuel is built around uranium – mining, fabrication, etc. – and not only is it the most economically fuel choice currently, but its costs would have to more than double for MOX-based fuels to be competitive. [12] Further

[2] As an aside, the underlying agreement that led to the PMDA also included the disposition of large amount of highly enriched uranium (HEU). The disposition path for the HEU is simple downblending with natural or depleted uranium to the traditional enrichment used in LWRs, and subsequent fabrication into reactor fuel.

complicating matters surrounding MOX fuel, is its inherent combination of military and civilian nuclear applications into one. The conjunction of these sectors poses significant challenges in regulation and authority. In the case of the MFFF, these challenges have proven to be debilitating.

Bringing the mission of MOX fuel production to the Savannah River Site was a massive undertaking, but the promise of economic stimulation and prestige in this facility as outcome made the work seem worth it. One can blame the lack of adequate annual funding, governmental organization, poor assessment practices, or a combination of all three [13], but the rerouting for the site's mission comes now from a rather obvious danger: the failure of the United States to uphold its nuclear weapons production capability. To correct for this negligence, the focused direction from the NNSA is for the MOX facility to be redesigned for plutonium pit production [14].

Policy Spotlight: Motivation for pit production

The 2018 Nuclear Posture Review (NPR) set an aggressive aim toward advancing our current nuclear capabilities. The nuclear triad – our comprehensive military nuclear weapons strategy – is defined as the combination of submarine launched ballistic missiles (SLBMs), intercontinental ballistic missiles (ICBMs), and air-launched cruise missiles (ALCMs) including their specific deployment vehicles and equipment. This immediate push to modernize the nation's nuclear arsenal has overflowed into the civilian sector, altering the path of a nuclear energy fuel source – the MFFF – to be analyzed for plutonium pit production. While seemingly drastic, it is important to pool collective efforts into revamping our national security infrastructure.

> Russian threat: The United States and Russian relations have taken many forms throughout the history of the United States. In the post-Cold War Era, many efforts were made to prevent another of its kind, but enduring differences in policy agendas have never truly brought the United States and Russia to a transparent understanding of the other. An even more dangerous and secret game of conflict has begun, venturing into the realm of cyber warfare and advanced nuclear technology. Pavel Podvig, an independent analyst of Russian nuclear affairs stated that "Russian efforts to develop hypersonic glide vehicles are explicitly aimed at evading U.S. missile defense systems" [15]. Russia has never seen a stall in their nuclear weapons program; they've been committed to keeping their arsenal current and effective. The same cannot be said for the United States – with the 1992 closure of the Rocky Flats Plant outside of Denver, Colorado, the United States faced a major setback. That particular plant was capable of creating over 1000 plutonium pits per year; currently, the Administration is struggling to establish enough resources and facility capability to produce 80 pits per year [16]. While the Rocky Flats Plant was in fault of many safety violations concerning waste, the decision to close rather than modernize and clean up has impacted the nation's readiness. In other words, the United States has been sleeping - relying on the mindset that as a nation, the United States of America is "number one." However, that is undoubtedly not true in the current global economy.

China threat: China exceeded the United States in terms of GDP with 18,228 billion dollars compared to the United States 17,393 billion dollars in 2014 and has only been expanding that differential since [IMF, Economist Intelligence Unit]. Additionally, China has the largest population, is the world's largest market for automobiles, cell phones, and e-commerce. They are the world's largest manufacturers in goods such as aluminum, ships, and computers [17]. As a country, China is expected to only continue their growth, not only in their economy, but in population, transportation, and living standards. [18] The United States is inefficient compared to China's advancements; as history has shown, the more a country increases its technological capabilities – be that faster computers, artificial intelligence, etc. – the more these technological capabilities translate into effective military applications.

Our two primary adversaries are pressing ahead while we have remained comfortable with the *status quo*. While the pursuit of MOX fuel was forged with good intentions, the abandonment of the facility mission can be justified through the utility of resources for immediate needs. That is to say, using what we have to create what we urgently need.

The other major policy influencer is the National Defense Authorization Act (NDAA) of 2019. Controversy over this bill was apparent in the different versions produced by the Senate and the House of Representatives. The Senate version, approved in June [19] prohibited the closure of the MOX facility while the House version supported its immediate shutdown. The compromise NDAA was signed into effect on August 13th, 2018 [20] and designated $220 million for the continued construction of the MOX facility. Although this seems like a large sum of money, when discussing nuclear construction bids, this is not nearly enough to make sustainable progress on the facility as discussed in earlier sections. This particular sum of money is even less than that designated toward the project in years previous, which may imply the inevitable cessation of the MFFF Project. While the idea of finishing the MOX facility and pursuing plutonium pit production in parallel at the SRS was proposed in the current NDAA and supported by the mayor of neighboring city Augusta, Georgia, it was never included in the assessment to meet the current administration's yearly pit quota [21].

One important aspect of previous NDAAs was the inclusion of a commitment from the Secretary "to remove plutonium intended to be disposed of in the MOX facility from South Carolina and ensure a sustainable future for the Savannah River Site" [23]. This statement was not included in the previous year's NDAA, and is meant to give assurances to the State of South Carolina that they will not become a "plutonium dump." In short, the MOX facility construction will continue with lesser amounts of money, while the DOE/NNSA solidifies a path forward for pit production at the SRS and removal of plutonium currently at the SRS for disposal elsewhere.

Lisa Gordon-Hagerty, the head of the NNSA, has expressed her support for the dilute and dispose method for the disposition plutonium, and the pursuit of plutonium pit production at the current MFFF [22]. For dilute and dispose, the plutonium is required to be recovered from its current form – either from plutonium pits or stored material – and converted to plutonium

oxide, two steps necessary for the production of MOX fuel as well. However, the subsequent steps involve mixing the metal oxide in a matrix of inert material to allow it to be dispositioned as transuranic waste. It is important here to note that dilute and dispose has been performed before. A portion of this plutonium was successfully shipped and disposed of in WIPP as part of the decommissioning of the Rocky Flats Plant and other DOE sites [25].

A major component in whether dilute and dispose succeeds is the ability for the Waste Isolation Pilot Plant to properly accommodate the full 34 metric tons of plutonium in addition to its currently assigned mission. The lifetime of WIPP is not eternal; the original contract has WIPP closing in 2050, with its current capacity estimated as being filled an astounding 24 years before this date. A reassessment of the Plant's status occurs every 5 years to insure that best practices are followed and the site is still capable of withstanding collapse or other failures.

The two major accidents that occurred in 2014 put all operations on hold for 3 years [25]. The first accident occurred on February 4th when a salt hauler vehicle's tire caught on fire, causing 6 workers to inhale smoke at a level which necessitated further treatment at Carlsbad Medical Center [26]. The second of which, occurring 10 days later, was a breached container, resulting from an incorrect repackaging operation that mixed organic material with nitrate-based salts, which reacted with one another and created enough pressure to break the container's seal, thereby spreading radioactive contamination in WIPP, with some material being dispersed to the above-ground environment [27]. Poor ventilation led to further complications and temporary shutdown of the plant until the system could be properly analyzed and corrected. This kind of shutdown tainted trust in the Plant's previous 15-year seamless operations, and does not encourage the rushed assessment of the plant for expansion. One technical issue for disposition of the additional plutonium is the limitations in place behind the Land Withdrawal Act, putting a cap on total transuranic waste (TRU) at WIPP to be 175,565 cubic meters [28]. However, the method of counting waste at the plant is being reassessed; some containers and stacking methods are not space efficient and thus, "filling up" areas prematurely when the actual level of TRU waste is lower than the space taken up. Out of WIPP's current 10 panels, 60% are filled and 20% have reduced capacity because of ceiling collapses[3] [31]. The construction of new panels are in the planning phase, as indicated in Figure 1.

[3] Note that collapses of the ceiling are expected, and inevitable without maintenance of the ceiling supports. One benefit of disposing of waste in WIPP's salt-based matrix is that the salt will "creep" in toward the waste and encapsulate it in place.

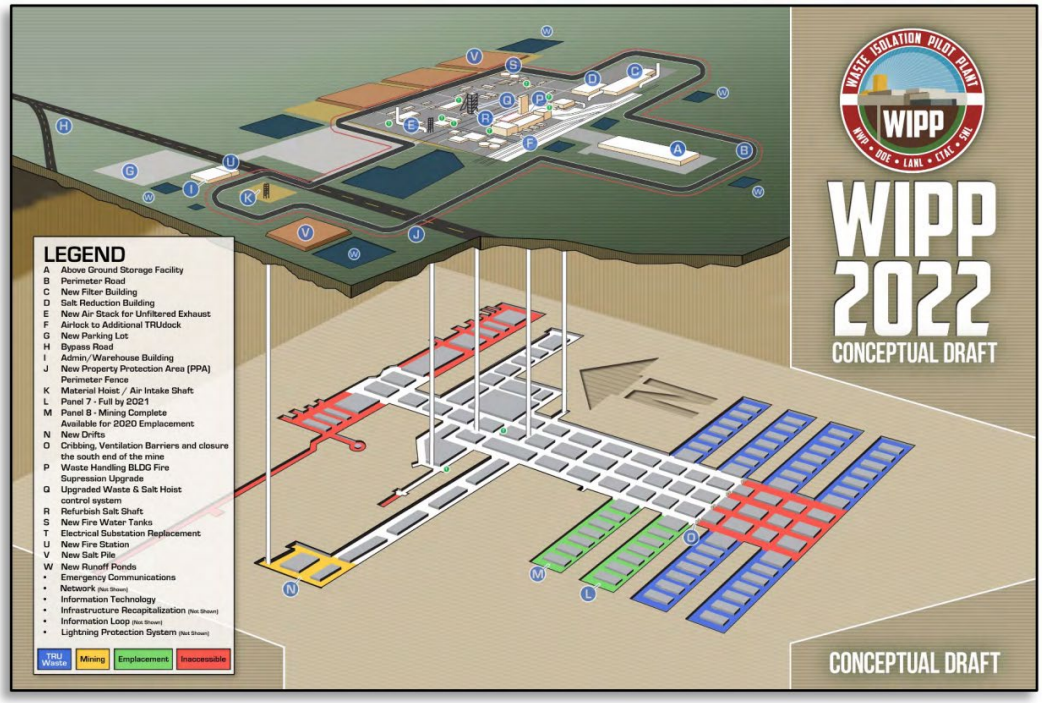

Figure 1: WIPP Repository Utilization (concept for future) [30].

The possibility of amending the act, as well as using deep borehole disposal for some of the waste requiring remote handling (higher levels of radiation) are other options on the table to allow for more waste disposition at WIPP in the future. However, even with these practices in place, WIPP will close in 2050. While this date seems far off, the timeline for converting 34 metric tons of plutonium with the current equipment and facilities available will more than likely exceed this cut off. The U.S. Government Accountability Office has recommended that immediate steps be taken by the DOE to revise WIPP's current capacity before the existing capacity is filled [25].

V. Additional Comments

The United States is still set on disposing of this plutonium per the PMDA, but Russia has suspended the agreement, so the question remains as to why we are persistent upon fulfilling the agreement? A trend the United States has taken in multiple areas concerning advanced nuclear energy applications has been to "take the high road." We have abandoned fast reactors, yet China, India, and Russia currently operate a number of these systems, which are designed to be able to consume a larger amount of actinides and result in a more efficient energy output [32]. The United States has also forbidden commercial reprocessing, while countries such as France continue to output approximately 75% of their energy in part from reprocessed fuel [33]. While energy policy in these countries favor their particular actions, it could be argued the United States could do the same if they so desired through carbon taxing non-renewable energy sources. The Unites States has operated in this fashion in hopes, one can speculate, to encourage others to follow. However this wishful thinking hasn't been demonstrably successful.

The fact that the United States is continuing with their plutonium disposition is most likely not going to inspire Russia to do the same out of good faith. In fact, it could be argued that the decision to dilute and dispose of this plutonium is rather wasteful in light of the current crisis. The remaining plutonium in those aged pits could be extracted for use in the production of new pits, or for eventual use as reactor feed material if the United States ever modified its nuclear energy policy set. The manufacturing of the original pits did not come free, and to spend additional taxpayer money to muddy them and bury them could be viewed as naïve at best and ignorant at worst. In addition to the dilute-and-dispose option, one could lobby for official withdrawal from the PMDA and pursuit of recycling, or simply storing for later use, the plutonium.

VI. Conclusion

In light of recent policy, it does not appear that a viable attempt is being made toward salvaging MOX. The $220 million set aside in the NDAA is hardly a realistic budget to make progress on the facility's construction. The overriding national push to improve nuclear security and revamp plutonium pit production capabilities will most likely overtake the current MOX facility mission, leaving the 34 metric tons of plutonium to be diluted and disposed of at WIPP. While the MFFF is another blemish in terms of large-scale nuclear projects being prematurely shut down through lack of planning, funding, and commitment, the nation must always remain flexible in utilizing our resources to meet immediate needs, specifically in the realm of national security. While the abandonment of the MOX facility will diminish the United States' chances to reconciling with Russia on the PMDA, in the scope of larger U.S.-Russian relations, this default is not as heavily weighted as perhaps the ongoing Russian interference in the 2016 U.S. presidential election, its annexation of Crimea, or larger cyber security trespasses. The United States appears determined to notionally hold up their end of the PMDA regardless of Russian approval of their disposal method, or the wisdom thereof.

VII. Acknowledgement

This material is based upon work supported under an Integrated University Program Graduate Fellowship. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the Department of Energy Office of Nuclear Energy.

VIII. References

1. "Agreement Between The Government Of The United States Of America And The Government Of The Russian Federation Concerning The Management And Disposition Of Plutonium Designated As No Longer Required For Defense Purposes And Related Cooperation" September 2000. http://fissilematerials.org/library/PMDA2000.pdf

2. "Russia launches commercial MOX fuel fabrication facility" *International Panel on Fissile Materials*, September 28, 2015. http://fissilematerials.org/blog/2015/09/russia_launches_commercia.html
3. Holt, Mark, Hikitin, Mary Beth D., "Mixed-Oxide Fuel Fabrication Plant and Plutonium Disposition: Management and Policy Issues" *Congressional Research Service,* December 14, 2017. 7-5700, R43125. https://fas.org/sgp/crs/nuke/R43125.pdf
4. Nikitin, Mary Beth D., Andrews, Anthony, Holt, Mark, "Managing the Nuclear Fuel Cycle: Policy Implicaitons of Expanding Global Access to Nuclear Power" *Congressional Research Service*, October 19, 2012. 7-5700, RL34234. https://fas.org/sgp/crs/nuke/RL34234.pdf
5. State of South Carolina V. United States Department of Energy, "Preliminary Injunction Order," Civil Action No.: 1:18-cv-01431-JMC
6. Harvard Kennedy School Belfer Center for Science and International Affairs, "Russia in Review, May 18-25, 2018" *Russia Matters.* https://www.russiamatters.org/news/russia-review/russia-review-may-18-25-2018
7. Reif, Kingston, "Russia Suspends Plutonium Agreement" *Arms Control Association: Arms Control Today,* November, 2016. https://www.armscontrol.org/ACT/2016_11/News/Russia-Suspends-Plutonium-Agreement
8. MOX Fuel Fabrication Facility Website, "About the MOX Project" MOX Services, LLC 2018. https://www.moxproject.com
9. Demarest, Colin, "U.S. Sen. Lindsey Graham criticizes MOX developments, plutonium inaction at hearing," *Aiken Standard,* May 24, 2018. https://www.aikenstandard.com/news/u-s-sen-lindsey-graham-criticizes-mox-developments-plutonium-inaction/article_8ecd1096-5f7c-11e8-95cb-971480bdfa56.html
10. The Advertiser-Tribune, "Bill would curb Cabinet control of nuclear agency" July 23, 2018. http://www.advertiser-tribune.com/news/national-news-apwire/2018/07/bill-would-curb-cabinet-control-of-nuclear-agency/]
11. The Western Journal, "Senate Bill Seeks to Wrench Control of Nuke Stockpile From DOE" July 22, 2018. https://www.westernjournal.com/defense-bill-would-curb-cabinet-control-nuclear-agency
12. Winblad von Walter, Tobias "Comparison of different nuclear fuel cycles for LWR applications" *Uppsala Universitet, Teknisk – naturvetenskaplig fakultet UTH-enheten*, April 2008. http://www.diva-portal.se/smash/get/diva2:461722/FULLTEXT01.pdf
13. Lubkin, Alexander, "What went wrong with US plutonium disposition" Bulletin of the Atomic Scientists, April 24, 2018. https://thebulletin.org/2018/04/what-went-wrong-with-us-plutonium-disposition
14. Reif, Kingston, "MOX Facility to Switch to Plutonium Pits" *Arms Control Association: Arms Control Today,* June, 2018. https://www.armscontrol.org/act/2018-06/news/mox-facility-switch-plutonium-pits

15. Gent, Edd, "Here's What we Know About Russia's Hypersonic Waverider Weapon" *Live Science*, May 24, 2018. https://www.livescience.com/62653-russia-hypersonic-weapon.html
16. Plutonium Pit Production Mission NNSA: National Nuclear Security Administration, Powerpoint, May 2018 https://www.energy.gov/sites/prod/files/2018/05/f51/Plutonium%20Pit%20Production%20Mission%20Fact%20Sheet%20May%202018.pdf
17. Allison, Graham, Destined For War
18. Lardy, Nicholas R., "U.S.-China Economic Relations: Implications for U.S. Policy" *Brookings*, April 25, 2001. https://www.brookings.edu/testimonies/u-s-china-economic-relations-implications-for-u-s-policy/
19. Exchange Monitor, "Senate Approves 2019 NDAA; Bill Would Loosen Warhead Development Rules" *Morning Briefing*, June 19, 2018. https://www.exchangemonitor.com/not-publish-senate-approves-2019-ndaa-bill-loosen-warhead-development-rules/
20. Demarest, Colin, "U.S. Joe Wilson: 2019 defense bill a good thing for SRS" *Aiken Standard,* August 24, 2018. https://www.aikenstandard.com/news/u-s-rep-joe-wilson-defense-bill-a-good-thing/article_364f0d58-a706-11e8-9985-83ce7b9c8cfa.html
21. Davis Jr., Hardie, "Resolution Supporting And Encouraging The Department Of Energy/National Nuclear Security Administration' S Consideration Of The Savannah River Site To Locate The Plutonium Pit Production Mission" March 15, 2018. http://www.lasg.org/MPF2/SCresolutions/AugustaGA_Resolution_6Mar2018.pdf
22. Demarest, Colin, "Trump's nominee to lead NNSA defends pit production priority, MOX aversion" *Aiken Standard,* February 8, 2018. https://www.aikenstandard.com/news/trump-s-nominee-to-lead-nnsa-defends-pit-production-priority/article_8f601a16-0cfd-11e8-b78a-4b5fe80fb12e.html
23. National Defense Authorization Act for Fiscal Year 2018. https://www.congress.gov/115/plaws/publ91/PLAW-115publ91.pdf
24. John S. McCain National Defense Authorization Act for Fiscal Year 2019. https://www.congress.gov/115/bills/hr5515/BILLS-115hr5515enr.pdf
25. United States Government Accountability Office, "Plutonium Disposition: Proposed Dilute and Dispose Approach Highlights Need for More Work at the Waste Isolation Pilot Plant" *Report to the Subcommittee on Strategic Forces, Committee on Armed Services, U.S. Senate,* GAO-17-390, September 2017. https://www.gao.gov/assets/690/686928.pdf
26. Wyka, Ted, "WIPP Underground Fire Accident Investigation Summary: February 5, 2014" *U.S. Department of Energy Office of Environmental Management*, March 2014. http://www.wipp.energy.gov/Special/AIB%20Summary.pdf
27. Brumfiel, Geoff, "Official Report: Nuclear Waste Accident Caused by Wrong Cat Litter" *National Public Radio: the two-way,* March 26, 2015. https://www.npr.org/sections/thetwo-way/2015/03/26/395615637/official-report-nuclear-waste-accident-caused-by-wrong-kitty-litter

28. Shrader, Todd, "WIPP Capacity: National Academy of Sciences" *U.S. Department of Energy Office of Environmental Management,* June 26, 2018. http://dels.nas.edu/resources/static-assets/nrsb/miscellaneous/ShraderWIPP8presentation.pdf
29. Rod Ewing article moving forward
30. Office of Environmental Management, "WIPP Town Hall Meeting" *Powerpoint Presentation,* April 19, 2018. Sponsored by the U.S. Department of Energy and the City of Carlsbad, NM.
31. Lane, Robert H., Kornreich, Drew E., "Data Analysis of Shipments to the Waste Isolation Pilot Plant" *Los Alamos National Laboratory, Applied Engineering and Technology-2,* LA-UR-21093
32. World Nuclear Association, "Fast Neutron Reactors" August 2018. http://www.world-nuclear.org/information-library/current-and-future-generation/fast-neutron-reactors.aspx
33. World Nuclear Association, "Nuclear Power in France" August 2018. http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/france.aspx